Original Article

Does anthropometric measurements correlate with hematological parameters after the adolescent growth period?

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Abstract

Introduction: Musculoskeletal growth is variable during adolescent period and reaches its maximum by 18 years, whereas hemopoietic parameters reach adult values by 15 years. After adolescence period, the blood parameters may vary with nutrition and built of the individual. The purpose of this study was to find out any correlation between anthropometric and hematological parameters after the adolescent growth period.

Methods: Total of 81 subjects (males: 20; females: 61), 18-22 years were analyzed for 4 anthropometric measures and 19 hematological markers. Blood was collected in citrate tubes and analyzed for hematological parameters.

Results: Difference between BMI sub-groups with respect to hemoglobin (Hb), red cell distribution width-standard deviation (RDW-SD) and red cell distribution width-coefficient of variation (RDW-CV) in males and females was not significant. In males, height showed negative correlation with mean corpuscular hemoglobin concentration (MCHC) and weight showed positive correlation with hematocrit. BMI positively correlated with Hb. Body surface area (BSA) correlated with red blood cell count (RBC) and hematocrit. In females, height, weight and BSA did not show significant correlation with any of the blood parameters. BMI correlated positively with mid-cell fraction and negatively with mean platelet volume. RDW-SD and RDW-CV did not reveal any statistically significant correlation with height, weight, BMI and BSA in both males and females.

Conclusion: In male subjects, hemoglobin concentration positively correlated with BMI whereas RBC count and hematocrit correlated with BSA. In females no such association was noted. RDW did not show any correlation with anthropometric measures in both genders.

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Keywords:
BMI; Body surface area; Hematological parameters; RDW; Anthropometry

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Introduction

The period between 13-18 years of age is characterized by growth spurts and puberty changes in boys and girls and is called as adolescent period. During this period growth rate is variable; with initial fast growth followed by a period of slow growth and...
then another spurt in growth. Sexual maturation or pubertal changes occur gradually over a period of time (Stanford Children's Health, 2016). In humans, growth spurt during adolescence is noticed primarily in long bones and other skeletal elements and continue till 18 years of age (Bogin B, 2016). Post-pubertal changes are seen not only in skeletal growth velocity and in muscle mass, but also in hemopoietic tissues. Many studies have shown that there are hematological variations at different stages of life. The level of hemoglobin, red blood cell count, packed cell volume are higher at birth and decrease thereafter, and attain adult values by the age of 15 years. However, levels in females are found to be less as compared to males owing to the effect of sex hormones on hemopoiesis (El-Hazmi and Warsy, 2001).

Anthropometric parameters like weight, height, body mass index (BMI) are frequently used as markers for assessment of nutritional status. Risk of mortality in seriously ill or hospitalized patients is increased if associated with low BMI. On the contrary, there is a decline in cognitive abilities and increased risk of many chronic diseases in patients with increased BMI (Housman et al., 2011). Body growth and development are also affected by malnutrition especially during adolescent period. The most common presentation seen in young adolescents is anemia, with iron deficiency being the most common underlying cause (Peter et al., 2012). Red cell distribution width (RDW), is a measure of the variability in size of circulating red blood corpuscles i.e. anisocytosis which is an indirect evidence of various factors affecting hemopoiesis including the nutritional status (Montagnana et al., 2011). An increase in RDW can also result from conditions that alter the shape of red blood cells due to the premature release of immature cells into the bloodstream, hemoglobinopathies or other hematological diseases (Skjelbakken et al., 2014). Increased RDW is also known to be a predictor of cardiovascular mortality in general population (Chen et al., 2010; Perlstein et al., 2009; Patel et al., 2009; Söderholm et al., 2015) and is also associated with increased mortality and adverse outcomes in renal and infectious diseases. Therefore, RDW is now considered as a new marker for estimating the risk of morbidity and mortality in various disease conditions (Li et al., 2015). Studies have been carried out to determine reference intervals for complete blood count and stratification based on age and sex in North America (Cheng et al., 2004), Europe (Nordin et al., 2004) and China (Qiao et al., 2014). Attempts have been made to find association of blood cell counts and anthropometry measures in pediatric age group (Kelishadi et al., 2010; Aypak et al., 2014). Available studies in general population cohorts especially young healthy adults correlating blood parameters with anthropometric measures are however limited, particularly in the Indian subcontinent. We hypothesize that after the adolescence growth period the nutritional status of an individual as assessed by anthropometry may majorly influence functioning of hemopoietic tissue as well as being reflected in peripheral blood parameters. The purpose of this study was to find out any correlation between anthropometric and hematological parameters including red cell distribution width in young adults.

Materials and methods

An observational study was conducted in Department of Physiology after obtaining approval from Institutional Review Board. A total of 81 subjects (males: 20; females: 61) within the age range of 18-22 years were included in this study. Informed consent was taken from all subjects.

Exclusion criteria

Subjects already on iron supplementation; with any chronic disorder like asthma, tuberculosis, etc.; with any acute infection at the time of study were excluded. Pregnant and lactating women were also excluded.

Anthropometry

Subjects’ height was measured to the nearest centimeter, while standing on a leveled ground. Subjects’ weight was recorded using the Krups weighing machine to the nearest 0.1 kg, while standing straight with minimal clothing and without footwear. Body mass index (BMI) was calculated as below.

\[
BMl \left(\frac{kg}{m^2}\right) = \frac{Weight (Kg)}{Height (m^2)}
\]
BMI categories were as follows (CDC, 2016):
1. Underweight: < 18.5 kg/m²
2. Normal Range: 18.5 - 24.9 kg/m²
3. Overweight: > 25 - 29.9 kg/m²
4. Obese: > 30 kg/m²

Subjects’ body surface area (BSA) was calculated using Du Bois and Du Bois formula (Halls, 2016).

\[
BSA = \frac{0.007184 \times \text{Height}^{0.725} \times \text{Weight}^{0.425}}{}
\]

Hematological parameters

Blood collection: Venous blood was drawn from antecubital vein under aseptic precautions in 2 ml tubes containing 3.2% buffered tri sodium citrate (J. K. Diagnostics, Rajkot, India). Blood samples were analyzed in an automated cell counter (BC-2800, Mindray Medical International Limited, Shenzhen, China) within 24 hours of collection for hemoglobin (Hb), red blood cell (RBC) count, mean corpuscular volume (MCV), hematocrit (Hct), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), red cell distribution width (RDW), total white blood cell (WBC) count, granulocytes (both absolute and percentage), lymphocytes (both absolute and percentage), mid cell fraction which is comprised of eosinophils, basophils, monocytes, and precursors of WBCs (both absolute and percentage), platelets, mean platelet volume (MPV) and platelet crit.

The values of Hb, RBC, Hct, total WBC, granulocytes, lymphocytes, mid-cell fraction, platelets, were multiplied by a factor of 1.1 to correct for sample dilution (1:9) which occurs by the use of citrate anticoagulant. However, the percent granulocytes and lymphocytes were recalculated by a simple percentage ratio of absolute granulocyte or lymphocyte to total WBC multiplied by 100. Sized parameters (MCV, RDW and MPV) and proportional parameters (MCH and MCHC) required no correction because these measurements were unaffected by dilution (Hanson, 2002; Perrotta et al., 1998). The reference range for red cell distribution width-standard deviation (RDW-SD) is 39-46 fl (Briggs and Bain, 2012) and for red cell distribution width-coefficient of variation (RDW-CV) is 11.6-14.6% (Vajpayee et al., 2011).

RDW-SD is an actual measurement of the width of the RBC size distribution histogram and is measured by calculating the width (in fl) at the 20% height level of the RBC size distribution histogram. This parameter is therefore not influenced by the average RBC size (MCV). Whereas, RDW-CV is calculated using standard deviation and MCV by below mentioned equation. Since RDW-CV is mathematically derived from MCV, it is therefore affected by the average RBC size (MCV) (Curry et al., 2016). We used citrate as the EDTA coagulated blood gives false high RDW (Wikipedia, 2016).

\[
RDW - CV (%) = \frac{1 \text{ standard deviation of RBC volume}}{MCV} \times 100%
\]

Statistical analysis

Data obtained was analyzed using SPSS 17.0 (SPSS Inc., Chicago, USA). For differences in mean, either Student’s t test or one-way analysis of variance (ANOVA) or Welch test was done depending on the significance of Levene’s test of homogeneity of variances. LSD (Equal variances assumed) and Tamhane’s (Equal variances not assumed) Post-Hoc tests were performed for statistical significance. Correlation statistics using Pearson’s correlation coefficient was done. Statistical significance was fixed at p<0.05. Continuous variables are presented as mean ± standard deviation.
### Table 2: Participant data and gender differences

<table>
<thead>
<tr>
<th>Gender</th>
<th>Male (n=20)</th>
<th>Female (n=61)</th>
<th>t-test, p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>19.90±0.85</td>
<td>19.70±0.99</td>
<td>t = 0.790, p = 0.432</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>171.20±5.24</td>
<td>157.61±4.67</td>
<td>t = 10.962, p = 0.000*</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>69.25±10.97</td>
<td>56.39±10.33</td>
<td>t = 4.756, p = 0.000*</td>
</tr>
<tr>
<td>BMI (kg/m(^2))</td>
<td>23.65±3.74</td>
<td>22.67±3.83</td>
<td>t = 1.002, p = 0.319</td>
</tr>
<tr>
<td>BSA (m(^2))</td>
<td>1.81±0.13</td>
<td>1.56±0.14</td>
<td>t = 7.017, p = 0.000*</td>
</tr>
<tr>
<td>Hemoglobin# (g/dl)</td>
<td>13.54±1.38</td>
<td>10.54±1.44</td>
<td>t = 8.157, p = 0.000*</td>
</tr>
<tr>
<td>RBC# (million/mm(^3))</td>
<td>5.44±0.58</td>
<td>4.73±0.53</td>
<td>t = 5.007, p = 0.000*</td>
</tr>
<tr>
<td>WBC# (/mm(^3))</td>
<td>6056±1371</td>
<td>7040±1806</td>
<td>t = -2.233, p = 0.028*</td>
</tr>
<tr>
<td>Lymphocytes# (/mm(^3))</td>
<td>2448±450</td>
<td>2593±622</td>
<td>t = -0.965, p = 0.337</td>
</tr>
<tr>
<td>Mid cell fraction# (/mm(^3))</td>
<td>380±140</td>
<td>451±247</td>
<td>t = -1.227, p = 0.224</td>
</tr>
<tr>
<td>Granulocyte# (/mm(^3))</td>
<td>3229±1177</td>
<td>3991±1358</td>
<td>t = -2.246, p = 0.027*</td>
</tr>
<tr>
<td>Lymphocyte# (%)</td>
<td>41.70±9.50</td>
<td>37.83±7.63</td>
<td>t = 1.848, p = 0.068</td>
</tr>
<tr>
<td>Mid-cell fraction# (%)</td>
<td>6.25±1.64</td>
<td>6.42±2.94</td>
<td>t = -0.239, p = 0.811</td>
</tr>
<tr>
<td>Granulocyte# (%)</td>
<td>52.04±9.52</td>
<td>55.69±8.35</td>
<td>t = -1.638, p = 0.105</td>
</tr>
<tr>
<td>Hematocrit# (%)</td>
<td>46.11±4.58</td>
<td>38.11±4.73</td>
<td>t = 6.610, p = 0.000*</td>
</tr>
<tr>
<td>MCV (fL)</td>
<td>85.21±6.39</td>
<td>81.01±8.92</td>
<td>t = 1.944, p = 0.055</td>
</tr>
<tr>
<td>MCH (pg)</td>
<td>25.02±2.76</td>
<td>22.35±2.96</td>
<td>t = 3.555, p = 0.001*</td>
</tr>
<tr>
<td>MCHC (g/dl)</td>
<td>29.36±2.01</td>
<td>27.74±1.69</td>
<td>t = 3.551, p = 0.001*</td>
</tr>
<tr>
<td>RDW-CV (%)</td>
<td>13.62±1.06</td>
<td>14.86±1.66</td>
<td>t = -3.886, p = 0.000*</td>
</tr>
<tr>
<td>RDW-SD (fL)</td>
<td>43.88±3.30</td>
<td>45.62±4.78</td>
<td>t = -1.519, p = 0.133</td>
</tr>
<tr>
<td>Platelet# (/mm(^3))</td>
<td>160435±52344</td>
<td>212805±53536</td>
<td>t = -3.817, p = 0.000*</td>
</tr>
<tr>
<td>MPV (fL)</td>
<td>9.24±0.61</td>
<td>9.22±0.61</td>
<td>t = 0.129, p = 0.897</td>
</tr>
<tr>
<td>PDW (%)</td>
<td>14.88±0.31</td>
<td>14.80±0.37</td>
<td>t = 0.820, p = 0.415</td>
</tr>
<tr>
<td>Plateletcrit# (%)</td>
<td>0.15±0.05</td>
<td>0.20±0.05</td>
<td>t = -3.640, p = 0.000*</td>
</tr>
</tbody>
</table>

#corrected values for dilution, *Level of significance: p<0.05
Results

The mean age of the study group was 19.75±0.10 years. Because of the known physiological effect of sex hormones on the erythropoiesis, analysis was carried out separately for either of the gender. The mean weight of males and females is 69.25±10.97 and 56.39±10.33 kg, respectively. The mean height of males and females is 171.2±5.2 and 157.6±4.6 cm, respectively (Table 2). The mean RDW-SD and RDW-CV in males and RDW-SD in females was within normal range, whereas RDW-CV in females was slightly above normal range (Briggs and Bain, 2012; Vajpayee et al., 2011). Figure 1 shows that 5 out of 20 (25.0%) male participants were anemic and figure 2 shows that 56 out of 61 (91.8%) female participants were anemic. Mean body mass index in underweight, normal and overweight participants is given in Table 3. The mean RDW-SD and RDW-CV in both males and females is given in Table 4.

Table 1 shows significant differences on independent sample t test between genders with respect to height, weight, BSA, WBC, Hb, RBC, hematocrit, MCH, MCHC, RDW-CV, platelets, plateletcrit. No significant difference was seen between genders with respect to body mass index, MCV and RDW-SD.

Linear regression analysis done to find out relation between Hb, RDW-SD and RDW-CV with BMI and BSA did not show any significant results in both genders. Figure 1 and 2 depicts the scattering of data for hemoglobin with respect to BMI in males and females respectively. We sub-grouped the individuals according to the BMI category (Table 3). Overweight and obese individuals were included under one group as the number of individuals in obese group was only 3. Difference between BMI sub-groups with respect to Hb, RDW-SD and RDW-CV in males (Table 4) and females (Table 5) was also not significant.

Gender specific results

Bivariate correlation using Pearson’s statistics was performed separately for males and females. Few of the hematological parameters significantly correlated with anthropometric measures.

![Fig.1. Variation in hemoglobin in relation to BMI in males with trend line](image-url)
In males, height showed negative correlation with MCHC ($r=0.539$, $p=0.014$). Weight was positively correlated with hematocrit ($r=0.454$, $p=0.044$). BMI positively correlated with Hb ($r=0.461$, $p=0.041$). BSA correlated with RBC ($r=0.446$, $p=0.049$) and hematocrit ($r=0.451$, $p=0.046$).

In females, height, weight and BSA did not show significant correlation with any of the blood parameters. BMI positively correlated with mid-cell fraction ($r=0.260$, $p=0.043$) and negatively correlated with mean platelet volume ($r=-0.0257$, $p=0.045$).

RDW-SD and RDW-CV did not reveal any statistically significant correlation with height, weight, BMI and BSA in both males and females.

### Discussion

The current study was done to evaluate any correlation between the anthropometric measurements and hematological profile especially red cell distribution width in young adults who have just completed their adolescence period; a period when both growth and blood parameters have already reached adult values.

In current study, 25.0% male and 91.8% female participants were anemic which was in contrast to the result obtained in a study done on Chinese population with only 31.1% women over 20 years of age were anemic (Qin et al., 2013).

Some of our study participants were underweight (Total: 16.04%, Males: 5.0%, Females: 19.7%) in contrast to Moafi et al (2011) study in which 19.4% of the total enrolled university going students (18.2% male, 20% female) were underweight. Major portion (55.55%) of our participants was in normal BMI category (Males: 65.0%, Females: 52.5%). The percentage of combined overweight and obese individuals was 30.0% in males and 27.9% in females (Total: 28.39%). Iranian study (Fujita et al., 2013) showed that 32.2% of total subjects were having normal weight and 37.7% and 30.1% were overweight and obese, respectively. In the study by Qin et al (2013) the prevalence of overweight/obese
status was 40.0% in females. In our study, BMI positively correlated only with Hb but a European study showed a positive correlation of BMI with Hb, RBC, and Hct (Barazzoni et al., 2014). Our study comprised of participants with ages between 18 and 22 years whereas this European study recruited subjects across a wider age group (18-69 years). Analysis of differences in Hb concentration among BMI categories revealed no significant result (Table 4 and 5) and this is consistent with the findings of Ghadiri-Anari et al. (2014) and Ausk et al. (2008) whereas Saxena et al. (2011) and Peter et al. (2012) reported an inverse relation of Hb with BMI in females.

Body surface area correlated with RBC count and hematocrit only in males and not in females in our study. On pubmed search we did not find any study which explored such relationship. Blood indices like MCV, MCH and MCHC did not show any association with BMI or BSA. Most of the studies have shown correlation between RDW and various disease states (Chen et al., 2010; Perlstein et al., 2009; Patel et al., 2009; Söderholm et al., 2015; Li et al., 2015) but only a few have reported correlation with anthropometry in healthy individuals. To the best of our knowledge no study has so far specifically explored the relation between red cell distribution width, body mass index and body surface area in young healthy adults. Findings of our study suggest that there is no association between RDW (both RDW-SD and RDW-CV) and anthropometric measures like height, weight, BMI and BSA. A study done in adolescent subjects by Fujita et al (2013) showed that increased RDW associated with overweight/obesity is the marker of inflammation. A Brazilian study (Oliveira et al., 2014) showed that total WBC count positively correlates with BMI but we did not find any correlation between total WBC or granulocytes or lymphocytes with BMI in both genders. Marzullo et al. (2014) concluded that neutrophils, monocytes and lymphocytes are raised in morbid obesity (BMI>40) when compared to normal BMI group which reflects the inflammatory process in these patients. None of our subjects belonged to morbid obesity group. A population based study in United States (Vuong et al., 2015) showed that total WBC count was positively correlated with BMI but not with anthropometric measures like height, weight, BMI and BSA. To the best of our knowledge no study has so far specifically explored the relation between total WBC and anthropometric measures like height, weight, BMI and BSA. Malignant hematologic disease was not present in any of the study subjects. The tables below summarize the data from our study.

### Table 3: Mean body mass index in underweight, normal and overweight participants

<table>
<thead>
<tr>
<th></th>
<th>Underweight (n=13)</th>
<th>Normal (n=45)</th>
<th>Overweight/obese (n=23)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI (kg/m²)</td>
<td>17.65±1.20</td>
<td>22.07±1.85</td>
<td>27.51±2.24</td>
</tr>
</tbody>
</table>

### Table 4: Mean values of Hb, RDW-SD and RDW-CV in male participants with respect to body mass index

<table>
<thead>
<tr>
<th></th>
<th>Underweight (n=1)</th>
<th>Normal (n=13)</th>
<th>Overweight/Obese (n=6)</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hb (g/dl)</td>
<td>12.5±0.0</td>
<td>13.2±1.5</td>
<td>14.3±1.0</td>
<td>F=1.669, p=0.218</td>
</tr>
<tr>
<td>RDW-SD (fL)</td>
<td>49.1±0.0</td>
<td>43.7±3.5</td>
<td>43.5±2.4</td>
<td>F=1.382, p=0.278</td>
</tr>
<tr>
<td>RDW-CV (%)</td>
<td>13.8±0.0</td>
<td>13.8±1.3</td>
<td>13.3±0.3</td>
<td>F=0.452, p=0.644</td>
</tr>
</tbody>
</table>

### Table 5: Mean values of Hb, RDW-SD and RDW-CV in female participants with respect to body mass index

<table>
<thead>
<tr>
<th></th>
<th>Underweight (n=12)</th>
<th>Normal (n=32)</th>
<th>Overweight/Obese (n=17)</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hb (g/dl)</td>
<td>10.0±1.5</td>
<td>10.7±1.3</td>
<td>10.6±1.6</td>
<td>F=0.976, p=0.383</td>
</tr>
<tr>
<td>RDW-SD (fL)</td>
<td>46.9±4.3</td>
<td>45.0±4.9</td>
<td>46.0±4.9</td>
<td>F=0.721, p=0.490</td>
</tr>
<tr>
<td>RDW-CV (%)</td>
<td>15.4±2.0</td>
<td>14.6±1.6</td>
<td>14.9±1.9</td>
<td>F=0.945, p=0.395</td>
</tr>
</tbody>
</table>
al., 2014) concluded that waist circumference rather than BMI (which is a widely used tool for assessing obesity in clinical practice) is the strong predictor for many blood parameters.

A Study by Charles et al. (2007) on individuals between 26 to 61 years found that there is no association of BMI with WBC and platelet count. Our study also did not yield any significant relationships between platelet count / platelet crit / platelet distribution width and BMI / BSA.

**Conclusion**

We conclude that there is no association between most of the hematological parameters and anthropometric parameters like height, weight, BMI and BSA. In male subjects, hemoglobin concentration positively correlated with BMI whereas RBC count and hematocrit correlated with BSA. In females no such association was noted. RDW did not show any relationship with anthropometric measures in both genders.

**Limitations of the study**

Since the normal range of different blood parameters is usually wide, our participant numbers were relatively less and require recruitment of more subjects. We suggest that a multi-centric study or a population based study be conducted to get a better understanding of variation in blood cell parameters with reference to age, sex, height, weight, BMI and BSA and to evolve reference intervals for the Indian population.

**Acknowledgments**

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**Conflict of interest**

The authors have no conflict of interest to declare.

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